BIOLOGICAL CONTROL OF BRUCHIDS (COL.: BRUCHIDAE) IN STORED PULSES BY USING EGG PARASITOIDS OF THE GENUS *USCANA* (HYM.: TRICHOGRAMMATIDAE): A REVIEW

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ABSTRACT

Because small-scale farmers in the tropics tolerate some insect damage and hardly use insecticides, there is scope for alternative methods of insect pest control such as the use of natural enemies. The scarce literature on *Uscana* spp. is reviewed. For the biological control of bruchids in stored pulses several strategies can be considered. The first strategy, classical biological control, has only been attempted a few times. Currently under investigation is the introduction of the European egg parasitoid *Uscana senex* for the control of *Bruchus pisorum* in Australia and Chili. The second strategy, releasing laboratory-bred natural enemies for inoculation and inundation, requires a high level of technology and is only appropriate for large-scale storage facilities. The third strategy of enhancing existing natural enemies by manipulation of the storage environment has not yet received much attention. Laboratory and field studies in the Netherlands and in Niger aim to achieve more effective control by the parasitoid *Uscana lariophaga* of the cowpea bruchid pests *Callosobruchus maculatus* and *Bruchidius atrolineatus* in the field and in traditional granaries. The paper discusses the results of studies on the effects of abiotic factors and nutrition on the development and performance of the parasitoid

INTRODUCTION

The use of natural enemies for biological control is only applicable in situations where the presence or contamination of insects and mites in storage is tolerated. The bulk of the harvest in the tropics is stored in traditional granaries. Under these conditions there is a high tolerance for low quality produce. In addition, pulses in tropical markets are often sold by volume which is not reduced by bruchid attack (Wegmann, 1983). As the use of pesticides constitutes high economic and health risks to poor farmers with few resources, the emphasis in the safe storage of pulses should be on biological methods of bruchid control: cultural, physical, biological, varietal, biorational and genetic control measures (see for a review: van Huis, 1989).

Girault (1911) described the genus *Uscana* (Trichogrammatidae) in 1911 and since then 16 species, all egg parasitoids, have been identified (Table I). Very few references are made in the literature, except for records and taxonomic descriptions. Therefore the few available data on the biology and ecology will be given or referred to in this overview.

Of the *Uscana* species with known hosts (11 out of 16), 9 attack bruchid and 2 buprestid eggs (Table II). *U. johnstoni* attacked the buprestid stemborer *Sphenoptera gossypii* in cotton in the Sudan (Waterston, 1926) and was considered to be a very valuable agent in the control of the pest (Table II). The parasitoid was found wherever the stemborer occurred and continued to breed between cotton seasons on stemborer eggs on alternative wild host plants.

Table I Taxonomic descriptions of *Uscana* species: reference, former genus or species and original location of specimens.

Uscana species	Reference and origen of specimens
Uscana Girault	Girault (1911). Doutt and Viggiani (1968). Steffan (1954).
U. bruchidivorax Steffan	Steffan (1954), France.
U. caryedoni Viggiani	Viggiani (1986), Congo.
U. diogenae (Risbec)	Risbec (1951)(*Lathromeris*), Senegal. Doutt and Viggiani (1968)(*Ufens diogenae*). Viggiani (1969)(new combination).
U. galtoni Girault	Girault (1912), (Australia).
U. giraulti (Soika)	Soika (1934)(*Lathromeris*), The Netherlands.
U. hodzhevanishvilii Fursov	Fursov (1987). Gruzia, Georgia, USSR.
U. inlaticornis (Nowicki)	Nowicki (1937)(*Lathromeris*), France.
U. johnstoni (Waterston)	Waterston (1926)(*Lathromeris*), Sudan.
U. johnstoni phoenicea Nowicki	Nowicki (1937)(*Lathromeris*), Turkey and Syria
U. lariophaga Steffan	Steffan (1954), Mali.
U. mukerjii (Mani)	Mani (1935)(*Chaetostricha*), India. Pajni and Singh (1973)
U. olgae Fursov	Fursov (1987). Southern European part of USSR.
U. pacifica (Doutt)	Doutt (1955)(*Lathromeris*), Saipan, Mariana Islands, Pacific.
U. princeps Steffan	Steffan (1954)(new name for *Lathromeris scutellaris*), Denmark Waterston (1926)(*Lathromeris scutellaris)*, United Kingdom.
U. semifumipennis Girault	Girault (1911), USA, Hawaii.
U. senex (Grese)	Grese (1923)(*Bruchoctonus senex*), USSR. Vasiljev (1947)(*Lathromeris bruchocida*), European parts of USSR. Fursov (1987) Southern European part of USSR and Caucasus USSR.
U. spermophagi Viggiani	Viggiani (1979), Italy.

U. marilandica Girault was renamed by Viggiani (1986) to *Uscanoidea marilandica* (Girault)(new combination)
U. pallidipes Girault (Girault (1915) from Trinidad was renamed by Viggiani (1986) to *Pterygogramma pallidipes* (Girault).

Table II List of *Uscana* species with known hosts and references (*U.= Uscana*; *A.= Acanthoscelides*; *B.= Bruchus*, *Br.= Bruchidius*; *C.= Callosobruchus*; *Car.= Caryedon*; *Z.= Zabrotes*). A (= *B.*) obtectus, *Car. serratus* (= *Car. gonagra, Caryoborus gonagra*); *C. maculatus* (= *B. quadrimaculatus*); *C.* (= *B.*) *analis*; *C.* (= *B.*) *chinensis*); *C.* (= *Pachymerus*) *phaseoli*; *Stator* (= *B.*) *pruininus*).

Uscana species	Host species	Reference
U. bruchidivorax	*B. fasciatus*	Steffan (1954)
U. caryedoni	*Car. serratus,Car. congense,* *C. rhodesianus*	Viggiani (1986)
	Car. serratus	Gagnepain and Rasplus (1989)
U. diogenae	*Diogena fausta*	Viggiani (1969)
U. hodzhevanishvilii	*Capnodis porosa*, (Col : Buprestidae)	Fursov (1987)
U. johnstoni	*Sphenoptera gossypii* (Col. Buprestidae)	Waterston (1926)
U. lariophaga	*C. maculatus*	Steffan (1954)
	C. maculatus, B. atrolineatus	van Huis et al (1990)
U. mukerjii	*C. maculatus*	Mani (1935), Mukerji and Bhuya (1936)
	C. maculatus, C. analis	Pajni and Singh (1973), Chatterji (1953)
U. olgae	bruchids (on *Lathyrus palustris*)	Fursov (1987)
U. semifumipennis	*C. maculatus*	Girault (1911), Paddock & Reinhard (1919)
	Stator limbatus, Mimosestus amicus	Mitchell (1977)
	Mimosestus sallaei	Hinckley (1960)
	B. rufimanus, Car. serratus	Steffan (1954)
	C. chinensis, Pachymerus gonager	Lepesme (1944)
	Car. serratus, Stator pruininus, *C. chinensis, C. phaseoli*	Bridwell (1918, 1919)
U. senex	*B. pisorum, B. lentis, B. affinis,* *Br. unicolor*	Fursov (1987), Steffan (1954)
	B. pisorum, A. obtectus	Vasiljev (1947)
U. spermophagi	*Spermophagus sericeus*	Viggiani (1979)

The first *Uscana* species identified, *U. semifumipennis*, was considered to be a very effective factor in reducing the natural increase of *Callosobruchus maculatus* in cowpea in Texas (Paddock and Reinhard, 1919). Percentages of parasitism of more than 67% were recorded. Karpova (1950) reported another very effective *Uscana* parasitoid, *U. senex*, of the pea weevil *Bruchus pisorum* in the Caucasus, USSR.

Rasplus (1988) reported that in Ivory Coast eggs of the bruchid species *Conicobruchus strangulatus*, *Bruchidius albizziarum*, *Callosobruchus rhodesianus* and *Specularius erythraeus* were parasitized by *Uscana* Girault species. Another species of *Uscana* parasitized eggs of *Bruchidius nodieri* on *Indigofera hirsuta*.

Prevett (1966) observed in Nigeria that females of *Caryedon albonotatum* on pods of *Acacia nilotica* completely cover each egg with black faecal material. He reasoned that this covering afforded protection against factors such as strong sunlight, low relative humidity and also parasitism by Trichogrammatidae, although no evidence of parasitism was found. Teràn (1962) recorded protection of eggs of *Caryedes germaini* by two "hyaline covers". Prevett (1966) also mentioned that *Caryedon fasciatum* covers the first egg laid on the single-seeded pod of *Combretum lamprocarpum* by another 2 or 3 eggs. The latter were, without exception, attacked by trichogrammatid parasitoids, whereas the lower egg hatched in a normal manner. The large eggs of this bruchid species supported two or three parasitoids each. *Mimosestes amicus* also deposits eggs one upon another, but probably only under stress (Mitchell, 1977). The parasitoid *Uscana semifumipennis* killed about 40% of the eggs, and heat and desiccation destroyed a further 40%. It was assumed that by placing one egg on top of the other, the cover egg is sacrified in order to double the chances of survival of the lower egg.

Parasitism by *U. caryedoni* of *Caryedon serratus* eggs on maturing seeds of *Piliostigma thonningii* pods in Ivory Coast is frequently masked by the heavy predatory activity of *Monomorium* ants (Gagnepain et al., 1986; Rasplus, 1988; also mentioned by Hinckley, 1960, for *U. semifumipennis* on *Mimosestes sallaei*). Predation amounted to 70% in unburned savannah and 30% in burned savannah. The ants cut the chorion of the parasitized and non-parasitized egg and feed on the contents. Despite the predation, Gagnepain and Rasplus (1989) encountered rates of parasitism between 3 and 30%, and recommended that before conclusions are made on the host specificity of *U. caryedoni* a search for the parasitoid on *C. cassiae* and *C. diallii* be done.

In order to use *Uscana* spp. in biological control three major strategies are envisaged:

- Classical biological control. Exotic natural enemies are introduced to obtain long-term depression and regulation of the pest species. This method is most frequently used against pests which have been introduced in a new area without their natural controlling agents. These agents are sought in the pest's area of origin and can also be used against native pests that lack efficient natural enemies.
- Inoculation/augmentation/inundation. Indigenous natural enemies are augmented by releasing laboratory-bred natural enemies and so adding to the existing population of beneficials.
- Conservation. The storage environment is manipulated to conserve and enhance the number of species, as well as the abundance of indigenous natural enemies.

The strategies for the trichogrammatid egg parasitoids of bruchids, *Uscana* spp. are reviewed with specific reference to the parasitoid *Triaspis thoracica* (Hym.: Braconidae). The species has been referred to in a number of publications as a promising agent for classical biological control programmes. The wasp of this species also oviposits in the egg but develops in the larva of the host.

CLASSICAL BIOLOGICAL CONTROL

The first record of an introduced *Uscana* sp. is in Hawaii. Bridwell (1918) mentioned the accidental introduction of *U. semifumipennis* from Texas into Hawaii. In 1913, *Caryedon serratus* was very abundant but soon after the introduction of the egg parasitoid the bruchid population declined. Parasitization rates of 90% were observed. Other species attacked were *Stator pruininus*, *Callosobruchus chinensis* and *C. phaseoli*. The parasitoid was considered to be, "a most valuable addition to the parasitic fauna of the island". In other places in Hawaii, where Bridwell (1919) found lower percentages of *C. serratus* eggs parasitized, he reasoned that this was because of the restricted number of host plant species. As the seed of these plant species only ripened in particular seasons, the bruchids did not have continuous breeding places and the parasitoid had a correspondingly limited opportunity for multiplication. *U. semifumipennis* was also introduced from North America into Japan in 1931 to control several bruchid species (Ishii, 1940).

The pea weevil, *Bruchus pisorum* is an important introduced pest of field peas in Australia. CSIRO, Australia, in collaboration with IIBC Delémont, Switzerland, is conducting surveys for natural enemies of *B. pisorum* in south-eastern Europe with the view to a future biological control programme in Australia (G.H. Baker, pers. communic.). Two parasitoids are being considered: *Uscana senex* and *Triaspis thoracica*. Similarly, in Chili control of *B. pisorum* is being attempted by introducing *U. senex* (E. Zuñiga, pers. communic.).

Biological control by introducing the braconoid *Triaspis thoracica* has also been reported a number of times. The parasitoid attacked 14 species of *Bruchus* and 7 of *Bruchidius* in France (Parker 1957). Khrolinskii and Malakhanov (1979) reported up to 80% parasitism of *Bruchus pisorum* by this larval parasitoid in Russia. Over a period of 4 years (1935-1939) introductions of *T. thoracica* from Austria and France were made in an attempt to control *Bruchus pisorum*, *B. rufimanus* and *B. brachialis* in the USA (Clausen, 1978; see also Larson et al., 1938). More than 140,000 specimens were released in Idaho, Oregon, California, Pennsylvania and North Carolina, but the parasitoid did not become established. In 1942 two releases were made of *T. thoracicus* in Canada, but neither resulted in establishment (McLeod, 1962). According to Turnbull and Chant (1961), the reason for the failures may be that *B. pisorum* is not the natural host of the parasitoid. The parasitoid was obtained from Austria where it was so abundant that the small numbers found parasitizing *B. pisorum* could not account for its large population. The parasitoid had difficulties piercing the egg of *B. pisorum*, and appeared more adapted to oviposit in eggs embedded in plant tissue.

Other larval parasitoids have also been imported into the USA: *Tetrastichus bruchivorus* Gahan in North Carolina and *Dinarmus acutus* (Thompson) in Oregon (Clausen, 1978). Field recovery has been reported for the latter only.

Aeschlimann and Vitou (1989) have recommended that biological control of the lucerne seed chalcid *Bruchophagus roddi* in Australia be attempted by introducing *Pteromalus sequester* Gussakovsky. This parasitoid has reduced significantly seed chalcid populations in Mediterranean France.

INUNDATION

Vasiljev (1947) indicated that *Uscana senex* could be considered for inundative releases to control the pea weevil *Bruchus pisorum* by rearing it under laboratory conditions in eggs of *Acanthoscelides obtectus* (at 25 °C and R.H. 75%). In the European part of the USSR, 70% of the eggs of *B. pisorum* in the field were parasitized by *U. senex*.

CONSERVATION

Manipulation of the storage environment should result in conditions less favourable for bruchid development and should enhance the effect of parasitoids and predators. Storage structures could be modified and new storage techniques introduced, such as the provision of food and shelter for the parasitoids and predators. Searching efficiency could also be enhanced by applying kairomones.

Uscana lariophaga

The Department of Entomology in Wageningen, the Netherlands, in cooperation with the Training Department of Crop Protection of the Agrhymet Centre in Niamey, Niger, are currently investigating ways of enhancing the effect of *Uscana lariophaga*, an egg parasitoid of *Callosobruchus maculatus* and *Bruchidius atrolineatus*, which are field and storage pests of cowpea in the Sahel. Field observations in 1987, found that 50% of the eggs of *C. maculatus* and 39% of *B. atrolineatus* were attacked (Lammers and van Huis, 1989). In granaries, *B. atrolineatus* enters a reproductive diapause after one generation (Germain et al., 1987), and *C. maculatus* continues to develop. Approximately 33% of eggs of *C. maculatus* in experimental granaries in Niger were parasitized in the first three months of 1989.

In Niger traditional granaries are constructed of banco, that is clay, manure and straw, or straw which consists of stems of millet or other Gramineae. The percentage of parasitism of *C. maculatus* eggs was significantly lower in straw granaries than in banco granaries. Therefore the effect of environmental factors, such as temperature, relative humidity and light intensity, were studied (van Huis et al., 1990). Temperature (15 to 45 °C) was found to affect longevity, development time, fecundity and mortality of the wasp. The intrinsic rate of increase (r_m) for *U. lariophaga* is highest at 35 °C (van Huis et al., 1990). In the temperature range, 20 to 35 °C, the r_m value of the parasitoid is six times higher than for the host *C. maculatus,* indicating that the parasitoid can be very effective. Relative humidity had only a limited effect on development time. Light intensity did not affect the performance of the parasitoid. These results are to be verified in Niger by simulating the population growth under the prevailing environmental conditions.

The effect of providing honey on the performance of *U. lariophaga* females to parasitize *C. maculatus* eggs was studied in the laboratory. Without food, which is the normal condition in granaries in Niger, the longevity of the female wasp at 30 °C was between 2 and 3 days, and significantly longer when no hosts were available (Table III). The provision of honey increased the longevity fivefold to 10-11 days with a maximum of 17 days. The fecundity increased threefold, from 25.5 to 74.5 parasitized eggs per female wasp. The honey-fed female wasps laid 55% of the eggs in the first 4 days, and after 11 days the number of parasitizations declined to a maximum of 4 per day. The sex ratio (proportion of females) of the offspring of honey-fed female wasps decreased significantly ($P \leq .01$) per day, and was probably due to depletion of sperm. Lim (1986) obtained a similar result with another trichogrammatid species. There was no difference in mortality between parasitized eggs of non-fed and fed wasps.

In order to obtain an indication of the potential growth of the population of fed wasps, the intrinsic rate of increase (r_m-value) was calculated using the equation (Howe, 1953)

$$\Sigma l_x m_x e^{-r*x} = 1$$

The life table gives the probability of survival at birth (l_x) of a female at age x, and the age-specific fecundity table gives the mean number of offspring (m_x) produced per unit of time by a female of age x. The r_m-value is calculated by trial and error. Results indicate a r_m-value of .278 for unfed and .321 for fed wasps. Exponential population growth was then calculated using the the equation

$$N_t = N_0 e^{r*t}$$

Where

N_t = size of the population after a period of t days;
N_0 = size of initial population
r = intrinsic rate of increase r_m
t = time in days.

The equation assumes that the host supply is unlimited and that the climate is constant in time and space. The calculation indicates that with an unlimited host supply, the fed population is at least three times larger than the unfed population after one month (Table III).

Therefore, feeding wasps in storage may potentially enhance growth of the parasitoid population. When considering application of this method, not only the presence of the host and its access to honey should be taken into account but also the effect on the searching efficiency of the parasitoid.

Table III. The effect of feeding honey on the parasitization by *Uscana lariophaga* of *Callosobruchus maculatus* eggs

Parameters	**Without honey**	**With honey**
Biology:		
Longevity (days)[1]: with hosts	2.1 (25) a	11.0 (22) b
without hosts	2.5 (25) c	10.0 (23) b
Number of parasitized eggs	25.5 (25) a	74.5 (22) b
Developmental time (days) '	9.3 (15) a	9.2 (15) a
Mortality of parasitized eggs	5.0 (22) a	4.0 (25) a
Population growth:		
Intrinsic rate of increase (r_m)	.278	.321
Number of wasps (x 10^5) after 30 days (N_0 = 100 wasps)	4 2	15.2

N.B Means followed by the same letter are not significantly different ($P \leq .05$; Mann-Whitney U-Wilcoxon Sum Rank W test).
1 All means tested among each other.

U. caryedoni

Delobel (1989) assessed the possibility of using *U. caryedoni* to control *C. serratus* in peanut granaries in Congo. The parasitoid attacks eggs of *Caryedon serratus* and *C. congense* on pods of the tree *Piliostigma thonningii* (up to 40% parasitization). However, in the groundnut granaries no indication of parasitization of *C. serratus* eggs could be found. Delobel (1989) reasons that being a relatively new species in Congo, *C. serratus* is probably not adapted to the granary conditions, for example, the parasitoid only attacked eggs in the upper layers of the stock. Although the parasitoid is an effective limiting factor on wild populations of *C. serratus* on the pods of *P. thonningii*, it is not a feasible biological control agent against the bruchids in groundnut stores.

DISCUSSION

Many natural enemies attack bruchids (de Luca, 1962; Hetz and Johnson, 1988) but little research has been done on their use in biological control. Southgate (1978) stated that the potential of these parasitoids for biological control cannot be assessed until the biology of the natural enemies is thoroughly understood. There is some information available on the provenance of bruchid species (Southgate, 1978), which may give an indication of the potential for classical biological control.

The *Uscana* species may be suitable for biological control because the direct damage inflicted by bruchids to leguminoceous seeds is prevented by parasitization of the egg. However, little is known of the biology and ecology of the species. Introduction of exotic species requires more information on their distribution, host specificity and climatic requirements.

The inoculation/augmentation/inundation approach does not seem very appropriate for small-scale farmers in the tropics. There are too many problems involved in the rearing and release of the natural enemies. However, the inundative approach, in particular for trichogrammatid species, could be considered for large-scale storage conditions (Arbogast, 1984).

Conservation and enhancement of endogenous parasitoids can only be considered where there is a certain tolerance to low quality produce as is the case in traditional granaries in developing countries. The ecological constraints to population growth of the parasitoids in traditional storage should be known so that new storage techniques can be proposed to eliminate them or reduce their effects. We demonstrated that the provision of honey to the parasitoid might increase the population growth, although more research is needed on the practical aspects of the proposed method. Effective implementation of simple modifications to storage structures and techniques must take into account the socio-economic and cultural aspects of the farmer.

ACKNOWLEDGEMENTS

The suggestions made by G.A. Pak are gratefully acknowledged. Thanks are due to G.J.K. Pesch for assistance with the literature references.

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LE CONTROLE BIOLOGIQUE DES BRUCHES (COL. : BRUCHIDAE) DANS LES STOCKS DE LEGUMINEUSES PAR L'UTILISATION DES OEUFS DE PARASITES DU GENRE *USCANA* (HYM. : TRICHOGRAMMATIDAE)

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RESUME

Parce que les fermiers des pays tropicaux qui pratiquent des cultures sur une petite échelle tolèrent les dommages causés par certains insectes et utilisent rarement des insecticides, la mise au point de méthodes alternatives d'élimination des déprédateurs par l'emploi d'ennemis naturels est à l'étude. Plusieurs stratégies peuvent être choisies dans l'éradication biologique des bruches des stocks de légumineuses. La première, l'élimination biologique classique, n'a été essayée que peu de fois. L'introduction du parasitoïde européen *Uscana senex* pour l'élimination de *Bruchus pisorum* en Australie et au Chili est actuellement à l'étude. La seconde, le lâcher d'ennemis naturels élevés en laboratoire dans le but d'inoculer et d'essaimer, demande un haut niveau de technologie et n'est convenable que pour les grandes exploitations. La troisième catégorie consistant à accroître le taux d'ennemis naturels existants en modifiant les conditions de stockage existantes n'a pas beaucoup retenu l'attention. Des études Néerlandaises et Nigériennes, faites en laboratoire et sur le terrain, tendent à améliorer l'élimination de deux bruches du niébe, *Callosobruchus maculatus* et *Bruchidius atrolineatus*, par l'emploi du parasite *Uscana lariophaga*, à la fois sur le terrain et dans les greniers. Le présentateur discutera des résultats des études sur les effets des facteurs abiotiques, des kairomones et de l'alimentation sur le développement et les actions du parasitoïde.